FINAL

Background Summary Report

Reclamation Reuse for Groundwater Recharge

Volume One • Summary

City of San Jose • Santa Clara Valley Water District

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PROPERTY OF SANTA CLARA VALLEY
WATER DISTRICT
5750 Almaden Expressway
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February 23, 1993

SFO27295.PZ.36

Mr. Jim Fiedler
Santa Clara Valley Water District
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Subject: Reclamation Reuse for Groundwater Recharge
Updated Background Summary Report

The purpose of this letter is to transmit the following updated reports, originally issued August 1992:

- Background Summary Report, Volume 1, Summary
- Background Summary Report, Volume 2, Chapter 2, Groundwater Recharge Opportunities
- Background Summary Report, Volume 2, Chapters 6 and 9 Cost Estimate Tables (6-7 through 6-12 and 9-1 through 9-8)

The revisions include updated cost estimates and the latest information on the Denver, San Diego, and Tampa health effects studies.

The updated estimates reflect treatment costs revisions, associated primarily with refinements to the zero brine discharge treatment, microfiltration, and sludge disposal cost estimates. The estimates are now expressed in January 1993 dollars.

Sincerely,

CH2M HILL

Mike Iverson

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Project Manager

cc: Ron Garner/City of San Jose

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FINAL

BACKGROUND SUMMARY REPORT

RECLAMATION REUSE FOR GROUNDWATER RECHARGE

Volume 1

SUMMARY

Prepared for

City of San Jose
and
Santa Clara Valley Water District

Prepared by

CH2M HILL

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Acronyms

ac-ft	acre foot
ac-ft/yr	acre feet per year
ADWF	average dry weather flow
ASR	Aquifer Storage and Recovery
BAAQMD	Bay Area Air Quality Management District
BAC	biologically activated carbon
BOD	biochemical oxygen demand
CCWA	Clayton County Water Authority
CDO	Cease and Desist Order
cfs	cubic feet per second
CVP	Central Valley Project
DBP	disinfection by-products
DOHS	Department of Health Services
DPRDP	Direct Potable Reuse Demonstration Plant
DWR	Department of Water Resources
EDR	electrodialysis reversal
EIR	environmental impact report
EPA	Environmental Protection Agency
µg/l	micrograms per liter
GAC	granular activated carbon
GC/MS	gas chromatograph mass spectrometer
gpd	gallons per day
gpm	gallon per minute
gpm/sf	gallons per minute per square foot
hp	horsepower
kW-hr	kilowatt hour
MCL	maximum contaminant level
mg/l	milligrams per liter
mgd	million gallons per day
N	nitrogen
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity unit
O&M	Operation and Maintenance
OCWD	Orange County Water District
PAC	powdered activated carbon
PCB	polychlorinated biphenol
pfu/gal	plaque-forming units per gallon
PPB	parts per billion
psi	pounds per square inch
RO	reverse osmosis
RPHL	recommended public health levels

RWQCB	Regional Water Quality Control Board
SBDA	South Bay Dischargers Authority
SCVWD	Santa Clara Valley Water District
SDLAC	Sanitation Districts of Los Angeles County
SJ/SC WPCP	San Jose/Santa Clara Water Pollution Control Plant
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
TSS	total suspended solids
THM	trihalomethane
THMFP	trihalomethane formation potential
TKN	total kjeldahl nitrogen
TOC	total organic carbon
UOSA	Upper Occoquan Sewage Authority
UV	ultraviolet
WCRWSA	West Coast Regional Water Supply Authority
WTP	water treatment plant

Reclamation Reuse for Groundwater Recharge
Background Summary Report

Introduction

The City of San Jose (City) and the Santa Clara Valley Water District (SCVWD) have jointly funded this study to investigate the development of groundwater recharge of reclaimed water in the County of Santa Clara. The project was originally conceived in 1989 when the City conducted a reconnaissance investigation of reclamation opportunities in Northern Santa Clara County (Reconnaissance Investigation) (Ref. 1-1). The resulting Reconnaissance Investigation Report, completed in March 1990, identified the possible beneficial reuse of highly treated wastewater from the San Jose/ Santa Clara Water Pollution Control Plant (SJ/SC WPCP). Two types of reclamation and reuse were identified: nonpotable and groundwater recharge. Although both types appeared feasible, the implementation issues, schedules, and costs were substantially different between the projects. Therefore, two separate projects were identified.

The Reclamation Reuse for Groundwater Recharge Background Summary Report updates and investigates in further detail the groundwater recharge aspects of the Reconnaissance Investigation and also incorporates the latest information available. This report is intended to identify the major opportunities, the major issues and constraints, the overall system requirements, and a possible future course of action for reclamation reuse for groundwater recharge.

The Executive Summary is divided into the following sections: Background, Study Objectives, Overview of Reclaimed Reuse for Groundwater Recharge, Overview of Groundwater Recharge Alternatives, Project Costs, Program Uncertainties, Conclusions, and Recommendations.

Background

The Reconnaissance Investigation identified two principal benefits associated with both nonpotable and groundwater recharge reclamation:

- Reduction of wastewater discharge and the associated conversion of salt marsh to either a fresh or brackish water marsh.
- Provision of a supplemental, reliable water supply source

Reclamation provides a unique opportunity to solve some of the issues facing both the City in addressing the flow reductions from the SJ/SC WPCP and the SCVWD in addressing supplemental, reliable water supplies. Reclamation presents such a solution while making use of a valuable resource: highly treated effluent.

Developing a reclamation and reuse groundwater recharge program for the Santa Clara Valley requires an understanding of wastewater issues, water supply issues, the results of previous investigations, the needs of the various agencies, the relevant physical characteristics of the study area, the quality of water to be reclaimed, and the facilities available. Given this background, groundwater recharge with reclaimed water has been identified, and treatment/conveyance facilities have been conceptualized.

The City is not responsible for water supply; that role belongs to SCVWD and to the several private and public water purveyors. Even so, the City has a strong interest in maintaining and providing additional supplies within the limits defined in various planning documents. This interest is, in part, based on the need to ensure a water supply that will support planned growth and ensure that ample supplies are available, which will prevent overdrafting and potential subsequent ground subsidence.

Wastewater Issues

The SJ/SC WPCP reliably treats and discharges a high-quality wastewater effluent to South San Francisco Bay (South Bay). However, because this area is environmentally sensitive, additional measures are necessary to further protect the area influenced by the plant's discharge. Reclamation effectively addresses flow constraints by reducing the quantity of effluent that is discharged.

The Basin Plan developed in the early 1970s prohibits wastewater discharge south of the Dumbarton Bridge. In an effort to gain an exception to the Basin Plan by demonstrating a net environmental benefit, the SJ/SC WPCP participated in a 5-year South Bay Dischargers Authority (SBDA) water quality monitoring study. Based on the study, the Regional Water Quality Control Board (RWQCB) staff has determined that water quality is enhanced because of localized increase of receiving water dissolved oxygen and the flushing effects of the discharge. The effects enhance the beneficial uses of noncontact recreation, estuarine habitat, and sport fishing. However, the RWQCB staff denied the request for exception based on the assertion that the plant discharge has been associated with conversion of salt marsh to either fresh or brackish water marsh. The salt marsh is habitat for two rare and endangered species, the California clapper rail and the salt marsh harvest mouse. Therefore, the RWQCB, as part of National Pollutant Discharge Elimination System (NPDES) Permit No. 89-012, determined that the SJ/SC WPCP's discharge location does not conform to the Basin Plan Policy and the Bays and Estuaries Policy.

The RWQCB's Cease and Desist Order (CDO) No. 89-013 states that the SJ/SC WPCP is responsible for the conversion of salt marsh between 1970 and 1985. To gain an exception to the Basin Plan prohibitions, the CDO states that the loss of salt marsh must be mitigated. The CDO specifies that eligible mitigation projects include creation or enhancement of salt marsh, reclamation that reduces annual average flows to 1970 levels (a required annual average flow reduction of up to 45 millions gallons per day [mgd]), relocation of the plant's discharge (construction of a deep-water outfall) that will result in a projected net increase of salt marsh habitat, or a combination of options to result in a net increase of habitat.

Subsequently, the State Water Resources Control Board (SWRCB), Order WQ 90-5 (October 4, 1990), required the RWQCB to amend the discharge permit to limit effluent flows to 120 mgd. This amendment was made in an effort to halt future salt marsh conversion. The RWQCB has interpreted the 120-mgd flow limit to be the average dry weather flow (ADWF) measured during the lowest 3-month flow period from May 1 through October 31. The low flow period for the SJ/SC WPCP, however, is generally the period starting in either March or April and extending for 3 months. Within the limits of the RWQCB's definition, the plant's low flow period is May, June, and July. The average plant flows in the May through July period are approximately 2 mgd less than in the June-July period. The City of San Jose subsequently developed and submitted an action plan in response to the pending flow limit.

The 1991 action plan contains a number of elements intended to fulfill the intent of the SWRCB order. Two of the elements are a 9- to 10-mgd nonpotable reclamation project and a 50- to 60-mgd potable groundwater recharge reclamation project. The RWQCB accepted the action plan as a viable alternative to the flow cap. Subsequent investigations have shown that the nonpotable reclamation project now has a potential 50- to 60-mgd capacity; the size of the potable groundwater recharge reclamation project is 20 mgd of reclaimed water capacity. The 20 mgd potable groundwater recharge project size is an approximate practical capacity which may be recharged into the aquifer while meeting the proposed DOHS regulations and requiring only limited relocations of existing potable water supply wells. The nonpotable Golden Triangle alternative is the smaller project at approximately 20 mgd ADWF (9 mgd annual average flow); two expanded nonpotable projects increase the estimated reuse to approximately 21 and 55 mgd ADWF (10 and 27 mgd annual average flow). The action plan has been updated to reflect current project capacities and schedules.

Water Supply Issues

Reclaimed water is increasingly being viewed as a very valuable resource. As a supplemental water supply, it is drought-resistant, and falls under local control. Reclaimed water is, therefore, seen as an important component of SCVWD's water supply. Reclaimed water adds to the available supply for the County.

The SCVWD is the water wholesaler of the region and uses a variety of sources including local surface water, groundwater, and imported water to meet the water demands of its customers (purveyors). The water purveyors include public and private entities such as the Cities of San Jose, Santa Clara, and Milpitas; the San Jose Water Company; the California Water Service Company; and the Great Oaks Water Company. The major water supplies for Santa Clara County are as follows:

- Local water supply generated through storage of local rainfall and runoff in surface reservoirs and groundwater basins
- Imported water supply purchased from the City of San Francisco through the Hetch Hetchy system
- Imported water supply purchased from the State of California through the South Bay Aqueduct system
- Imported water supply purchased from the U.S. Bureau of Reclamation through the San Felipe system

When the County reaches full buildout, half of the average raw water supply will be from imported sources. Water imported from the state and federal projects, along with local surface runoff, is used to recharge the groundwater and supply three water treatment plants. These three plants, Santa Teresa, Rinconada, and Penitencia, have a combined capacity of 215 mgd. Imported water from Hetch Hetchy is piped directly to the local water retailer's distribution system. Local water supplies include the water impounded in the various surface water reservoirs, which is subsequently used for groundwater recharge, and the miscellaneous stream and subsurface flows that also recharge the groundwater basins. The Anderson and Coyote Reservoirs in the Diablo Range are the two largest surface water reservoirs and generally have carryover storage capacity from one year to the next.

Although the SCVWD has done extensive planning to secure a reliable water supply, several factors indicate that reclaimed water would be a valuable supplemental water source. These factors include the uncertainty of obtaining the full contracted state and federal water project entitlements; the current drought; the variability of local supplies; the current Bay-Delta hearings, which have reallocated water rights for the preservation of fish and wildlife; and an increasing concern for the quality and reliability of Delta water. Reclaimed water can provide a relatively high-quality, reliable, drought-resistant addition to the water supply of the County.

The SCVWD is preparing a system overview that identifies a number of possible sources of new water supplies, including conservation, water purchases and transfers, nonpotable reclamation, reservoir construction, groundwater recharge reclamation, and desalinization. Preliminary results indicate that the SCVWD needs to develop new water supplies totaling approximately 15,000 acre-feet per year (ac-ft/yr) (approximately 15 mgd) for its long-term water needs through the year 2020. These quantities are preliminary and will be updated as part of the 1992 system overview. During a critical dry period, the preliminary results have indicated that the SCVWD needs an additional 105,000 ac-ft/yr.

The limiting factor for groundwater recharge of reclaimed water may be the minimum reclaimed water for groundwater recharge that the groundwater basin is able to accept and store in a wet year, given the available local surface water and imported water supplies. The use of a guaranteed quantity of high-quality reclaimed water is considered a potential source for this required future water supply. The SCVWD has several concerns regarding the viability of recharging reclaimed water, and these include concern over the potential for contaminating the groundwater basin, concern regarding health effects, the general public's reservations, high project cost, and effects on existing supplies.

Point and Nonpoint Source Issues

Another reclamation objective is to reduce the amount of metals that enter the lower portion of the South Bay. Groundwater recharge and nonpotable reclamation will directly affect metals in the Bay by decreasing the metals load in proportion to the wastewater flow directed from the Bay. These restrictions also affect options for treatment processes and residuals disposal, specifically reverse osmosis (RO) brine disposal. Currently, there are two primary sources of heavy metal constituents: nonpoint sources, such as stormwater runoff, and point sources, such as discharge from the SJ/SC WPCP.

Overall waste load allocations have not been set for the South Bay, but it is anticipated that they may be implemented, through RWQCB actions, in the future. It is expected that the waste load allocation using a zero brine discharge option would have to be divided between point and nonpoint sources. Implementation of a reclamation and reuse program using a zero brine discharge option would reduce the total metals load to the Bay and thus could help improve discharge requirements associated with waste load allocations of metals from both point and nonpoint sources.

Nonpotable Reclamation Project

The Golden Triangle Nonpotable Reclamation Project Facility Plan was published in January 1992. The Nonpotable Reclamation Project consists of a first phase to supply approximately 20 mgd ADWF (9.1 mgd annual average flow) of irrigation water for agricultural and landscape uses in the Golden Triangle area of San Jose, including Santa Clara and Milpitas. An expanded nonpotable project was identified and would supply Milpitas and other outlying areas, increasing the total nonpotable reclamation to approximately 55 mgd ADWF (27 mgd annual average flow). Project capital costs were estimated to range from $53,000,000 to $62,000,000 in 1993 dollars, equating to between $545 per acre-foot and $590 per acre-foot for capital costs.

Study Objectives

The objective of this project is to investigate the use of reclaimed water to recharge the groundwater basin in northern Santa Clara County. Currently, for potable reuse, the recharging of reclaimed water into a groundwater aquifer is the only method acceptable by today's regulations. The present regulatory requirements will be summarized in this study, as will other reuse projects and health-effect studies. Four groundwater recharge alternatives and associated cost estimates have been developed, including treatment, conveyance, and residual disposal costs.

Overview of Reclaimed Reuse for Groundwater Recharge

Groundwater Recharge Definition

In general, reclamation is the process by which wastewater is treated to acceptable standards for the intended reuse method. The Nonpotable Reclamation Project will treat the SJ/SC WPCP effluent to California Department of Health Services (DOHS) standards for unrestricted public access and exposure when used for industrial, landscape, and agricultural irrigation. The reclamation reuse for groundwater recharge project would treat the SJ/SC WPCP effluent to DOHS standards for groundwater recharge and then use the reclaimed water to recharge the local groundwater basin. Reclaimed water recharged to the groundwater basin would eventually need to be diluted according to DOHS requirements so that there is a maximum of 50 percent reclaimed water at the potable wellhead. Reclamation reuse for groundwater recharge requires extensive additional treatment to produce a high-quality product water before it is used for recharge.

There are two types of groundwater recharge with reclaimed water: planned recharge and incidental or unplanned recharge. The latter occurs when water is recharged as a result of a wastewater disposal operation, and the amount of recharge and contribution to a domestic system cannot be quantified. Examples of this type of recharge are associated with most wastewater land disposal operations involving evaporation and percolation ponds. Two California and three other "planned" recharge operations in the United States are described below.

Concerns about the health effects of groundwater recharge have changed over the years and may be summarized as including microbiological concerns involving infectious disease, acute health effects from chemicals, and long-term health impacts generally causing either cancer or reproductive defects. The basic concern in all of this work relates to the potential impact on the domestic water supply; recharge projects must be designed and operated in a manner to ensure the safety and integrity of the drinking water supply now and in the future.

Regulatory/Institutional Requirements

The two primary regulatory agencies that govern reclamation projects include the California DOHS–Office of Drinking Water and the RWQCB. The California DOHS–Office of Drinking Water has jurisdiction over domestic water supplies and groundwater recharge. The RWQCB sets the waste discharge permits and interprets the state and federal nondegradation policies. The SWRCB adopted a resolution in 1968 which, by strict interpretation, requires that recharge water be treated to the extent that use would not degrade the existing water supply, although the resolution did not define what constituted degradation. The federal nondegradation policy is part of the Clean Water Act. The main regulatory agencies have been brought into this study to ensure that their concerns are identified and addressed. There are concerns that new drinking water standards that may be promulgated in the future–particularly for cancer-causing or reproductive defect-causing organic compounds–may affect existing and planned recharge projects. If this project proceeds, then the proposed treatment processes and testing procedures will be designed to answer as many of the uncertainties as possible and identify those areas where more information is needed. The issue of the unidentified fraction of the remaining Total Organic Carbon (TOC) following treatment will be the primary point in the investigation of all potential recharge and drinking waters. Some of the questions that exist today cannot be addressed until testing data are available.

The quality of the recharged water must not adversely affect the quality of the drinking water and must not degrade the character of the recharged water and thereby endanger the existing recharge operation and groundwater storage capacity. The treatment processes reviewed in this study have been selected to produce a product water that will fulfill these requirements and provide the necessary reliability and treatment redundancy. Table 1 summarizes water quality information on SJ/SC WPCP effluent, the DOHS draft groundwater recharge regulations, the U.S. Environmental Protection Agency (EPA) drinking water standards, SCVWD groundwater, and imported water from state and federal projects.

The DOHS draft groundwater recharge regulations include the following specific criteria:

Table 1
Water Quality Information

	SJ/SC WPCP Effluent[a]		DOHS Groundwater Recharge[b]	EPA Drinking Water Standard[c]	SC Valley Groundwater[d]	Imported Water
	Avg.	Max.				
TDS (mg/l)	870	—	500	500	350	321
Nitrate (as N)(mg/l)	17.0	23.3	10	10	3.4	<1
Total Nitrogen (as N)(mg/l)	19.3	25.9	—	—	3.4	<1
Arsenic	<2.0	<5	50	50	—	2
Cadmium	<0.5	<0.5	10	10	1 to 2	—
Chromium, Total	1.1	1.8	50	50	<1 to 5	—
Copper	7	9	1,000	1,300	<10 to 50	<5
Lead	<1	<2	50	15	<10 to 30	<5
Mercury	<0.2	0.3	2	2	—	—
Nickel	13	17	—	—	<10	—
Silver	3	4	50	50	<5	—
Zinc	53	76	5,000	5,000	<100	—
Total Coliform (MPN)	2.5	8.0	—	1	—	—
Turbidity (NTU)	1	2	—	1[h]	—	—
TOC (mg/l)[f]	11	16	20/5/6/2[e]	—	0.2 to 1.5	3 to 4
Chloroform[f]	6.5	—	—	g	—	—
Bromodichloromethane[f]	6	—	—	g	—	—
Chlorodibromomethane[f]	3.5	—	—	g	—	—
Biochemical Oxygen Demod (BOD)(mg/l)	3	4	—	—	—	—
Suspended Solids (SS)	1.6	2.0	—	—	—	—
Grease and Oil (mg/l)	<1.5	<2.3	—	—	—	—
Settleable Solids (mg/l)	0	0	—	—	—	—
pH	6.8	7.0	—	6.5 to 8.5	—	—
Alkalinity (as $CaCO_3$)(mg/l)	129	—	—	—	—	—
Conductivity (μohm/cm)	1,392	—	—	—	—	—
Hardness (as $CaCO_3$)(mg/l)	238	—	—	—	—	—
Magnesium (mg/l)[i]	29	—	—	—	—	—
Calcium (mg/l)[i]	53	—	—	—	—	—
Silica (mg/l)[i]	10	—	—	—	—	—
Temperature (°C)	17	25	—	—	—	—
Dissolved Oxygen (mg/l)	6.5	8.0	—	—	—	—
Apparent Color	17.0	20.0	—	15.0	—	—
Floating & Suspended Water	None	None	—	—	—	—
Odors	None	None	—	—	—	—

[a] 1991 data. Provided by the SJ/SC WPCP.

[b] Proposed standards, expected to be finalized in 1992.

[c] EPA Primary and Secondary Drinking Water Standards. All Standards listed are primary standards (indicating a relationship between concentration and public health protection) except copper, zinc, the color, and TDS, which are secondary standards (taste and odor related), pH, which is based upon aesthetic criteria, and cyanide, which is health based.

[d] Groundwater Quality Monitoring Program for the Santa Clara Valley Groundwater Basin. Santa Clara Valley Water District, July 1986.

[e] 20% Dilution: 20 mg/l surface recharge, 5 mg/l direct injection.
50% Dilution: 6 mg/l surface recharge, 2 mg/l direct injection.

[f] There are 40 organics with drinking water standards, 15 of which have been tested for, with only THMS being found. Another 124 organics without standards have been tested for with 6 of them found above the detection limit.

[g] Total THM standard of 100 mg/l.

[h] Scheduled to decrease to 0.5 NTU in June 1993.

[i] Limited 1991/1992 data. Provided by thge SJ/SC WPCP.

Note: μg/l except as noted.

- TOC
- Minimum depth to groundwater beneath a surface recharge facility
- The minimum residence time of the reclaimed water in the aquifer
- Maximum horizontal distance to the nearest potable well
- Reclaimed water dilution; the maximum percentage of reclaimed water pumped from the surrounding potable water supply wells

Table 2 summarizes the two treatment standards–groundwater nondegradation and composite–that may be applied to the groundwater recharge project. Because this project would be a planned groundwater recharge operation, meeting the groundwater nondegradation standard may be necessary. Treating reclaimed water to the nondegradation standard may also be viewed as desirable or mandatory from a public acceptance point of view. However, reclaimed water treated to the composite standard may not affect groundwater any differently than the current recharge operation affects it. Additional information available after pilot testing, water characterizations, and additional health effects work will help to finalize a decision on whether to proceed to full-scale implementation.

The groundwater nondegradation standard requires that the treated reclaimed water from the treatment plant match the average water quality of the Santa Clara Valley subbasin groundwater, or a total dissolved solids (TDS) concentration of 350 milligrams per liter (mg/l), a nitrogen concentration of 3.4 mg/l, and a TOC of approximately 1.0 mg/l.

The composite standard is derived from several sources. The composite standard is based on treating the reclaimed water to a quality such that, when it is blended with dilution water imported from state or federal water projects, the combined recharge water quality matches the average groundwater's TDS and nitrogen quality. The composite standard for TOC concentrations is based on the reclaimed water quality meeting the DOHS draft groundwater recharge regulation requirements and having less TOC content than the imported water currently being recharged. Thus, the composite standard allows a TDS concentration of 350 mg/l, a nitrate concentration (as nitrogen) of between 5.8 and 10 mg/l with the blended concentration (reclaimed water plus dilution water) being 3.4 mg/l, and a TOC concentration of between 1.6 and 2.5 mg/l. The nitrogen portion of the composite standard also considers the DOHS draft groundwater recharge regulations, which set 10 mg/l as a maximum. In the case of a 20 percent dilution (20 percent reclaimed water, 80 percent dilution water), the DOHS draft standard of 10 mg/l is the limiting requirement rather than the reclaimed water concentration of 13 mg/l, which would provide a concentration of 3.4 mg/l nitrogen

Table 2
Treatment Standards

Standard	Reclaimed Water Concentration			Based On
	TDS mg/l	NO_3 as N mg/l	TOC mg/l	
Groundwater nondegradation	350	3.4	1.0	Limited groundwater data
Composite 20 percent dilution[a]; surface recharge or direct injection	350	--	--	Current average groundwater concentrations
	--	10	--	Import and local surface water currently used in percolation ponds. N = 0-1 mg/l; DOHS draft Groundwater Recharge Regulations allow 10 mg/l or less. Blend to 3.4 mg/l or less.
	--	--	2.5	Import water currently used in percolation ponds, TOC 3 to 4 mg/l; DOHS draft Groundwater Recharge Regulations allow 20/5 mg/l.
Composite 50 percent dilution[b]; surface recharge	350		--	Current average groundwater concentrations
	--	5.8	--	Import and local surface water currently used in percolation ponds, N = 0-1 mg/l. Blend to 3.4 mg/l or less.
	--	--	2.5	Import water currently used in percolation ponds, TOC 3 to 4 mg/l; DOHS draft Groundwater Recharge Regulations allow 6 mg/l.
Composite 50 percent dilution[b]; direct injection	350	--	--	Current average groundwater concentrations
	--	5.8	--	Import and local surface water currently used in percolation ponds N = 0-1 mg/l. Blend to 3.4 mg/l.
	--	--	1.6	Import water currently used in percolation ponds, TOC 3 to 4 mg/l; DOHS draft Groundwater Recharge Regulations allow 2 mg/l.

[a] Twenty percent reclaimed water is combined with 80 percent import water/surface water/treated water before surface or injection well recharge.

[b] Fifty percent reclaimed water is combined with 50 percent import water/surface water/treated water before surface or injection well recharge.

when blended with local and imported water. The imported water TOC is as high as 5 mg/l, averages 3 to 4 mg/l, and exceeds the average groundwater TOC; the TOC concentrations of surface water from local sources are not available. With full stream RO and no granular activated carbon (GAC), the groundwater recharge treatment plant effluent has an estimated TOC concentration of 1.6 mg/l. The DOHS draft standards allow a greater concentration of TOC, varying from 20 mg/l (surface recharge at 20 percent dilution) down to 2 mg/l (direct injection at 50 percent dilution), and are not found to be controlling.

The safety of recharge operations has been questioned because of concerns about infectious disease that can be spread by bacteria, parasites, and viruses. Historically, disease has been spread by the irrigation of produce and other crops with inadequately or undisinfected wastewater effluent. Advances in disinfection technology and microbiological sciences have solved these problems, and the current and pending groundwater recharge regulations by the state contain safeguards to protect against infectious disease through a combination of chemical disinfection (chlorination, etc.) and "natural disinfection" (time of travel and distance through the ground). Concerns about the possibility of acute (short-term) contamination centered mostly around the potential for water to be contaminated with nitrogen as nitrate, and its impact on infants. These concerns, and the potential for contamination with other compounds that might present a short-term threat, are addressed in the regulations. These regulations prohibit the recharge of water that does not meet the drinking water standards, and in the case of nitrate, limit the concentration to a fraction of the drinking water standard. The state and federal nondegradation policies also apply, and can be more stringent than the drinking water standards in some cases, such as nitrogen.

The final area of concern involves the potential for long-term health effects. Within the last 20 years there has been an increasing emphasis on the potential for contamination of all water supply sources from organic compounds. The discovery of groundwater contamination in various areas of the United States from industrial and other sources has led to the development and adoption of an expanded list of drinking water standards for organic compounds such as trichloroethylene and similar products that can cause cancer or reproductive defects in humans.

The health effects concerns relate not to the short-term identifiable organic compounds but rather to the "unknown" organic compounds that may be present and identified only as TOC. To date, the method by which this concern has been addressed includes a combination of: (1) source control to limit the types of compounds that may be present in the recharge water, (2) advanced treatment to reduce the amount of TOC in the recharge water, and (3) limitations on the amount of recharge water that may be present in the extracted water used for the domestic potable supply.

Groundwater recharge proposals, such as the one being considered by the City and the SCVWD would include extensive testing to determine the character of the influent into the SJ/SC WPCP, the existing recharge water, the existing groundwater, the treated surface water, and the proposed treated recharge water. The types and amounts of identifiable organic compounds present in all sources would be determined before recharge operations start. Specific health effects testing using microbial or animal species to determine short- or long-term impacts may be required based on water quality testing results. The results from chemical testing of the various recharge waters generally determine whether health effects testing is performed.

Previous Reuse Projects

There are now two major groundwater reuse projects in California and three other major potable reuse projects in Georgia (stream flow augmentation to a surface source), Texas (direct injection into a potable aquifer), and Virginia (discharge to a source reservoir). The project that most closely resembles the proposed project in San Jose is the Los Angeles County Sanitation District's groundwater recharge project in the Montebello Forebay-Whittier Narrows area. In this project, 50,000 ac-ft/yr of reclaimed water is blended with local surface water and imported water and recharged in approximately 700 acres of recharge basins. This project has been in operation since 1962 and was the subject of a major health effects study. Under the currently proposed regulations, this project, to be permitted, would have to add additional treatment processes. The other major recharge project in California has been authorized to inject 100 percent reclaimed water into the Orange County groundwater to form a seawater intrusion barrier, with a minor portion (about 5 percent) reaching potable production wells. Currently, approximately two-thirds of the recharge is reclaimed water. The project has been in operation since 1976 and has used many of the processes proposed for this reclamation reuse groundwater project.

Health Effects Studies

Four major health effects studies have been performed on water reclamation projects in the United States. The first study was done by the Los Angeles County Sanitation Districts in conjunction with the DOHS, the EPA, the SWRCB, and the Department of Water Resources (DWR). The $1.6 million health effects study was completed in 1984 and included water quality characterization, toxicological and chemical studies, soil studies to evaluate percolation as a treatment process, groundwater movement studies to determine the relative contribution to downstream wells, and epidemiology on the exposed population. The project concluded that there were no adverse health effects, but realized it did not include a long-term health evaluation.

Three other studies that are in progress in Denver, Tampa, and San Diego greatly expand the body of knowledge on health effects. The Denver study included full-scale animal testing and 5 years of operation with a 1-mgd demonstration plant designed to produce water for direct reuse. The final stages of the health effects study are being prepared, and a report is due in 1993. The Tampa study also is complete, and the toxicological report will include teratology and reproductive effects as well as short-term animal testing. The report is being prepared and is expected to be finalized in 1993. The final study has just been finished in San Diego, and the complete report was presented to the City. The results from these new studies, including the only long-term health effects work done in the Denver study, should be available for full review in 1993 following completion of the reports and peer review. At that time a more complete assessment of the health effects can be made. Preliminary reports from the researchers indicate that no adverse impacts have been seen to date, but that final judgement should be reserved until the work has been completed. A Blue Ribbon Committee recommended that possible pilot work proceed along with the chemical testing and other analytical work to determine the quality of the product and other waters before a decision is made to design and proceed with specific toxicological or other tests. Cost estimates are uncertain at this time but will be made following the analytical work that would accompany the pilot testing.

Preliminary work done with the California DOHS has shown that they are comfortable with the process the City and SCVWD are using to date. DOHS representatives present at the Blue Ribbon Committee meeting expressed their satisfaction with the progress to date. No new information has been developed since that meeting, and no new regulatory requirements have been promulgated that would affect the proposed project.

Overview of Groundwater Recharge Alternatives

There are two principal methods for groundwater recharge: surface recharge and direct injection. Groundwater recharge entails two difficult issues. The first is how to ensure that the reclaimed water dilution requirements at the surrounding public water supply wells are met (that the maximum allowed concentration of reclaimed water is not exceeded). The second is how to set the minimum continuous amount of reclaimed water that can be recharged, given that reclaimed water may displace local and imported water supplies, both in normal and extreme precipitation years.

Project Alternatives

Developing groundwater recharge of reclaimed water comprises the evaluation of three types of options: treatment options, conveyance options, and facility location options. Treatment options for reclaimed water are evaluated by criteria relating to water quality requirements (which treatment methods will enable reclaimed water to satisfy promulgated standards). Conveyance options and facility locations options, which are partially interdependent, are evaluated differently, based on criteria of cost, practicality, land availability, and distance to reclaimed water source and recharge.

This study evaluates two locations for a groundwater recharge treatment plant and two methods for groundwater recharge. The various treatment plant and recharge locations have unique conveyance needs to deliver influent to the groundwater recharge treatment plant, to deliver reclaimed water and dilution water to the groundwater recharge point, and to convey residual brine away for disposal. There is also an option to combine the nonpotable distribution piping with the groundwater treatment plant influent piping.

The groundwater recharge plant location options are an area near San Francisco Bay and the SJ/SC WPCP at a City-owned site on Zanker Road, or in the groundwater aquifer forebay area generally near the SCVWD headquarters and the Guadalupe recharge system. The forebay area, shown on Figure 1, is the area over the unconfined aquifer and is approximately an area south of the I-280 and I-680 freeways.
The two methods for groundwater recharge are surface recharge using the existing SCVWD groundwater recharge facilities or direct injection using new groundwater injection wells. The new injection wells can be located near San Francisco Bay or in the forebay area.

Four combined treatment and conveyance/location alternatives have been identified for detailed evaluation. These project alternatives, which are shown on Figure 2, are summarized as follows:

- Project Alternative 1 locates the groundwater recharge treatment plant near SJ/SC WPCP, uses SCVWD surface recharge facilities, and has separate groundwater recharge conveyance piping.

- Project Alternative 2 locates the groundwater recharge treatment plant near the SCVWD recharge facilities, uses surface recharge facilities, and has combined nonpotable and groundwater recharge conveyance piping.

- Project Alternative 3 locates the groundwater recharge treatment plant near SJ/SC WPCP, uses direct injection recharge with new wells located near the San Francisco Bay, and has separate groundwater recharge and dilution water conveyance piping.

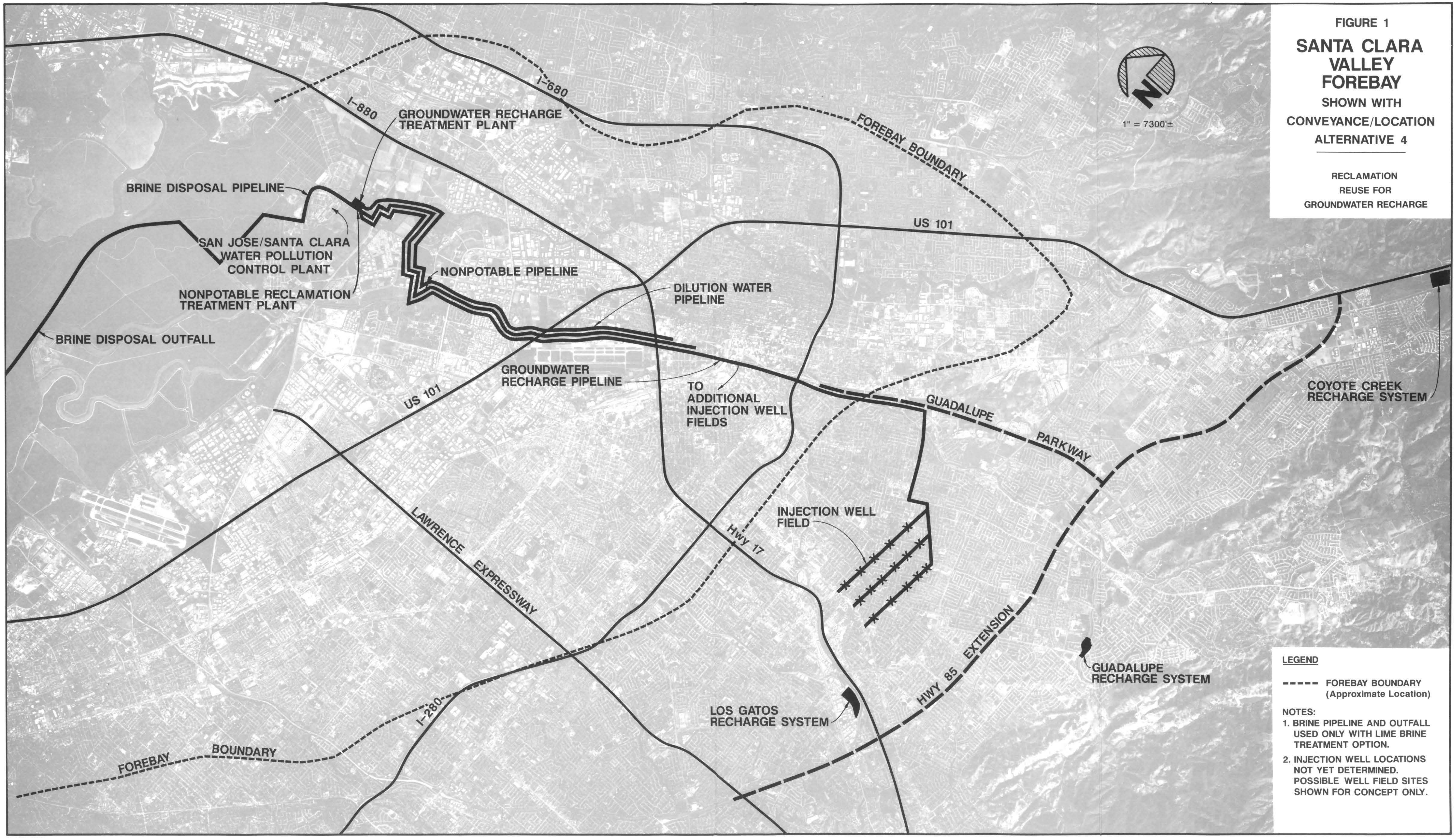
- Project Alternative 4 locates the groundwater recharge treatment plant near SJ/SC WPCP, uses direct injection recharge with new wells located in the forebay, and has separate groundwater recharge and dilution water conveyance piping.

FIGURE 1

SANTA CLARA VALLEY FOREBAY

SHOWN WITH
CONVEYANCE/LOCATION
ALTERNATIVE 4

RECLAMATION
REUSE FOR
GROUNDWATER RECHARGE


N
1" = 7300'±
I-680
I-880
FOREBAY BOUNDARY
GROUNDWATER RECHARGE TREATMENT PLANT
BRINE DISPOSAL PIPELINE
SAN JOSE/SANTA CLARA WATER POLLUTION CONTROL PLANT
NONPOTABLE RECLAMATION TREATMENT PLANT
NONPOTABLE PIPELINE
US 101
DILUTION WATER PIPELINE
BRINE DISPOSAL OUTFALL
GROUNDWATER RECHARGE PIPELINE
TO ADDITIONAL INJECTION WELL FIELDS
US 101
GUADALUPE PARKWAY
COYOTE CREEK RECHARGE SYSTEM
INJECTION WELL FIELD
LAWRENCE EXPRESSWAY
Hwy 17
HWY 85 EXTENSION
GUADALUPE RECHARGE SYSTEM
LOS GATOS RECHARGE SYSTEM
I-280
FOREBAY BOUNDARY

LEGEND

- - - - FOREBAY BOUNDARY (Approximate Location)

NOTES:

1. BRINE PIPELINE AND OUTFALL USED ONLY WITH LIME BRINE TREATMENT OPTION.
2. INJECTION WELL LOCATIONS NOT YET DETERMINED. POSSIBLE WELL FIELD SITES SHOWN FOR CONCEPT ONLY.

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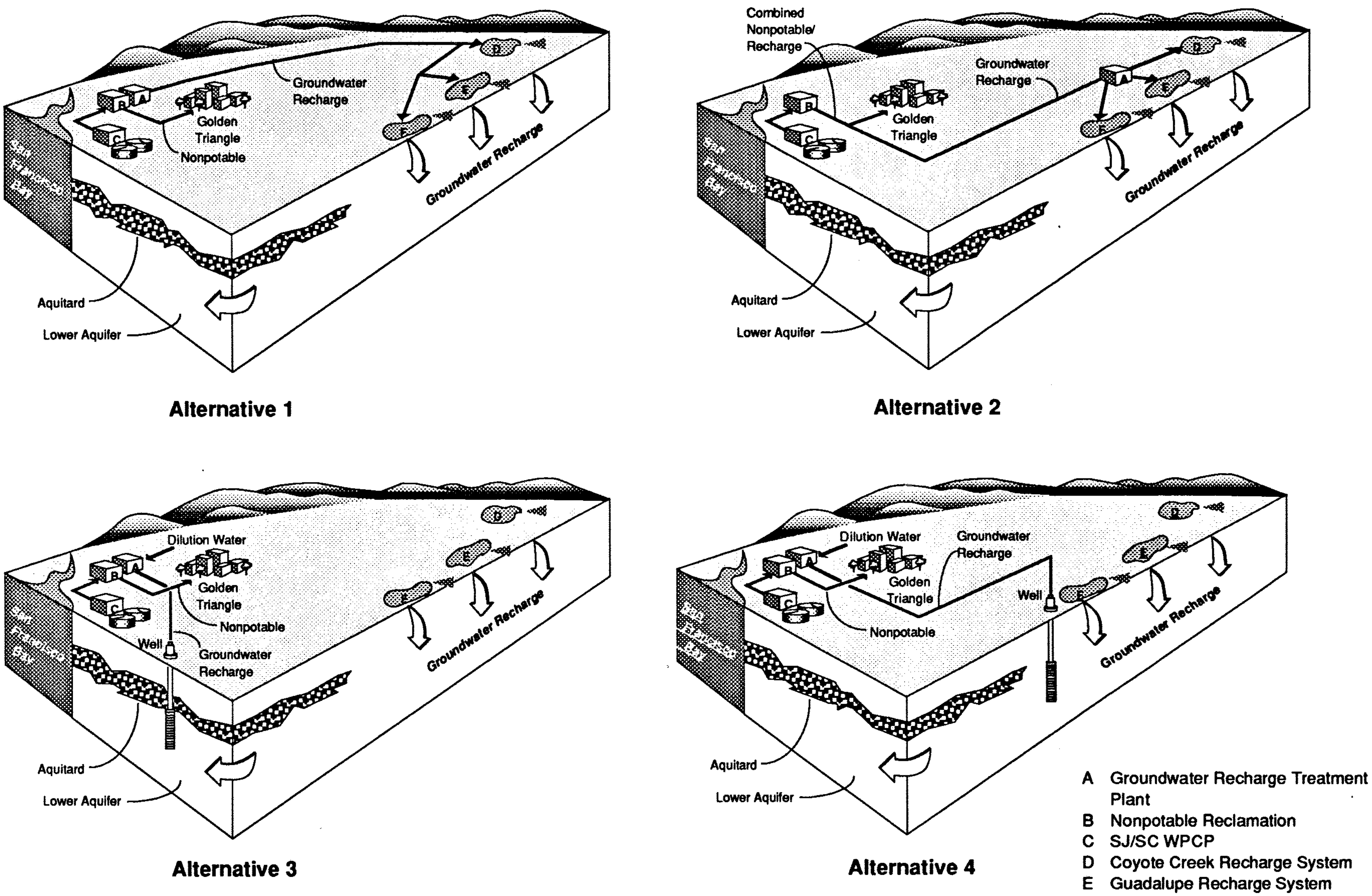

Alternative 1

Alternative 2

Alternative 3

Alternative 4

A Groundwater Recharge Treatment Plant
B Nonpotable Reclamation
C SJ/SC WPCP
D Coyote Creek Recharge System
E Guadalupe Recharge System
F Los Gatos Recharge System
⁓ Import Water/Surface Runoff

Brine Line Pipeline/Outfall Not Shown
Dilution Water Pipeline Not Shown

FIGURE 2
PROJECT ALTERNATIVES
CONVEYANCE/LOCATION COMBINATIONS

Aquifer Recharge

For background, groundwater generally flows from the southern portion of the north county toward the San Francisco Bay, where it is withdrawn from the lower aquifers by water supply purveyor wells. A regional aquitard exists toward the Bay, limiting groundwater recharge in this confined zone. The surface recharge facilities are located in what is called the forebay or the unconfined area where there is no aquitard to reduce or prevent groundwater recharge to the lower aquifer. Figure 1 shows the San Jose area, the existing recharge systems, and the approximate forebay boundary. Surface recharge of reclaimed water would use portions of existing SCVWD facilities including Los Gatos Creek, Guadalupe River, and Coyote Creek recharge facilities. These facilities recharge the Santa Clara Valley groundwater subbasin, which provides an average of 150,000 ac-ft/yr of annual water supply.

The DOHS draft groundwater recharge criteria were discussed in the Regulatory Requirements section. Local model analysis of the groundwater basin indicates that 20 mgd of reclaimed water (40 mgd total recharge water) can be recharged into the Santa Clara Valley subbasin using direct injection or possibly surface recharge methods while meeting the DOHS regulatory requirements, with the following assumptions and limitations, and preliminary groundwater analysis conclusions:

- Dilution and reclaimed water are assumed to be blended to a 50/50 mixture before recharge, and the minimum residence times are assumed to be 150 percent of the DOHS standard (18 months minimum instead of 12 months minimum). The 50 percent reclaimed water blend above ground allows 100 percent certainly that the DOHS criterion has been met for the maximum allowable reclaimed water concentration in the nearest water supply well. Increasing the residence time accounts for the possible error in residence time calculations.

- Surface recharge could be accomplished but 26 water supply wells, assumed to be potable, around the Coyote recharge facility will be within 500 feet of the ponds and will need to be abandoned (total capacity of between approximately 200 ac-ft/yr and 2,100 ac-ft/yr, depending on maximum pumpage year). The minimum depth to groundwater appears to be 10 to 15 feet, and thus the minimum 20-foot criterion may not be met. Similar estimates for the Los Gatos and Guadalupe recharge facilities were not in the scope of this study.

  The DOHS and RWQCB might be persuaded to disregard the depth to groundwater requirement because the reclaimed water meets direct injection water quality standards. In this case, additional water supply wells might need to be abandoned if the surface recharge facility were made to meet the DOHS direct injection minimum horizontal separation criterion of 2,000 feet.

- Direct injection of reclaimed water in the forebay area appears feasible. A well field of approximately 12 wells over an area 4,000 feet by 6,000 feet could inject approximately 12.5 mgd of reclaimed water or 25 mgd total recharge water; one water supply well would need to be abandoned. The well to be abandoned has only a 60 gallon per day (gpd) capacity (0.06 ac-ft/yr).

  As an approximate practical upper limit, the same well field could inject approximately 15 mgd reclaimed water or 30 mgd total, by injecting through 16 wells over a 12,000 feet by 12,000 feet area; 17 water supply wells, assumed to be potable, would need to be abandoned with an approximate combined pumping capacity of approximately 1.1 mgd (1200 ac-ft/yr).

  A separate well field(s) with either 5 or 7 direct injection wells would be used to recharge an additional 10 or 15 mgd of recharge water (5 or 7.5 mgd reclaimed water) to make up the 40 mgd recharge total. The groundwater model simulations indicate that this additional 10 or 15 mgd can likely be recharged into the basins. Evaluation of these injection wells for DOHS criteria was not included in the scope of this study.

- Direct injection of significant quantities of reclaimed water near SF Bay and SJ/SC WPCP does not appear to be practical due to very limited injection well capacity in this area.

- Surface recharge or direct injected reclaimed water may be used to supplement local or imported water now used for recharge.

- In extremely dry years, lack of available dilution water may limit the ability to recharge reclaimed water by either surface or direct injection.

- In extremely wet years, lack of recharge capacity may limit the ability to recharge reclaimed water by surface spreading.

Estimates of the accuracy of the above results depends on the parameter in question and the recharge method. With the above assumptions, when evaluating DOHS criteria, the accuracy errors are mitigated or accounted for.

Two basinwide groundwater model simulations were run based on two sets of input, including forebay direct injection totaling 40 mgd (20 mgd reclaimed water and 20 mgd dilution water). Projected groundwater levels at approximately 15 locations around the basin were then compared to a water level standard. The standard to which the water levels were compared was assumed to be either 25 feet below ground surface, or the highest recorded groundwater level in the last 15 years. This standard was used as a measure of the maximum acceptable level for these simulations. Simulation No. 1 was a 5-year run with average conditions. Simulation No. 2 was an 8-year run, with 3 years of average conditions followed by 5 years of wet conditions.

These groundwater modeling simulations' results must be interpreted with caution. First, these results are based on only two sets of input, even though many input combinations could provide different results. These two simulations provide general results for specific sets of circumstances. Different initial assumptions for direct injection, surface recharge, pumping, and hydrological conditions will result in groundwater level predictions different from those calculated by the first two simulations. Second, there may be other simulations that could provide more realistic groundwater level predictions. The two simulations represented only average and wet conditions and did not include periodic droughts. Third, errors in the model are difficult to quantify. Based on previous calibrated model runs, these errors are probably less than 25 percent. It is important to note that because of grid/scale limitations these groundwater model simulations do not specifically investigate compliance with proposed DOHS criteria. And lastly, aquifer capacity estimates may vary by as much as plus or minus 50 percent due to uncertainty in assumed aquifer parameters, such as transmissivity.

The results of the two groundwater model simulations can be summarized as follows:

- Results from the two simulations indicate that it is feasible to recharge 20 mgd of reclaimed water. These results are based on the simulation input conditions only, with properly placed direct injection wells, assuming that some water supply pumping wells are redistributed to the forebay area near the direct injection wells. The redistributed pumping wells would reduce the localized high groundwater conditions caused by the direct injection. Additional unknowns not accounted for in this model, such as actual soil conditions or water chemistry, may alter these results.

- The areas between Los Gatos Creek and Guadalupe River and north and west of Los Gatos Creek appear to be more promising for direct injection of large quantities of water than the Santa Teresa Basin (the area near the Coyote recharge ponds). The Santa Teresa Basin may be useful for direct injection of smaller quantities of water.

- Results suggest that groundwater levels in some areas of the basin may approach steady state conditions, balancing recharge flows into and water supply flows pumped out of the basin, before reaching the maximum acceptable aquifer level.

- Hydrographs suggest that the Santa Teresa Basin (near the Coyote recharge ponds) is not directly influenced by the injection wells in the other basins west of Guadalupe River. It appears that groundwater levels exceed the maximum acceptable level only because of high natural recharge in wet years.

- Water levels in many parts of the basin rise under average conditions, but did not reach the maximum acceptable level during the simulation period.

- The 5 wet years resulted in greater pressures in the confined zone under the aquitard (very low-permeability clay layer), rather than actually increasing groundwater levels near the ground surface.

- Adding additional water supply wells near areas of local mounding could likely prevent high local groundwater levels above the maximum acceptable level. The added supply wells could be additional pumping capacity or relocated pumping capacity.

SJ/SC WPCP Effluent Quality

Existing SJ/SC WPCP effluent data are summarized in Table 1. This table presents 1991 average and maximum SJ/SC WPCP general/bacteriological/organic data, along with the drinking water standard, if applicable. Tests were performed looking for 151 organic compounds, 21 of which have drinking water standards. Of the eight detected organic compounds, only three trihalomethanes (THM) have applicable drinking water standards. The total detected THMs were well below the standard (16 vs. 100 µg/l). The effluent was not analyzed for other drinking water organics that are regulated by the state or federal government.

If a groundwater recharge demonstration plant is built to conduct pilot testing before a full scale-plant, it will be necessary to select a location at SJ/SC WPCP from which to take wastewater for both the demonstration plant and the full-scale plant.

Based on accessibility, lack of impact on plant operations, and the relatively low THM concentration, the SJ/SC WPCP dechlorinated effluent is the recommended point from which to draw influent for a groundwater recharge demonstration plant. The SJ/SC WPCP chlorination disinfection process does not appear to need modification for the groundwater recharge plant because of the low THM concentrations. Effluent nitrogen exceeds the groundwater levels, thus denitrification will be needed before reclaimed water is recharged to the groundwater. Separate denitrification filters at the groundwater recharge treatment plant are recommended.

Treatment Processes

The influent water quality to be treated is shown in Table 1. Alternative treatment processes have been identified based on the required quality of reclaimed water to be recharged. Various full flow and partial unit process flows can be combined to produce reclaimed water that meets either the groundwater nondegradation standards or the composite TDS, TOC, and nitrate standards. The treatment process assumes that the influent is the SJ/SC WPCP dechlorinated effluent that has been rechlorinated in the nonpotable project to conform to Title 22 unrestricted nonpotable reclaimed water use.

The groundwater recharge treatment processes would include nutrient removal, filtration, demineralization, organics removal, and disinfection. Nutrient removal would occur in fixed film denitrification filters. RO would be used for demineralization. RO pretreatment for the removal of suspended solids, organics, and low soluble salts is necessary and would be either a high pH lime process followed by clarification and filtration, or a microfiltration unit. Microfiltration is a newly emerging, low-pressure membrane technology, with the membranes formed in hollow tubes. Microfiltration has the advantage that it does not produce a large volume of chemical sludge. GAC would provide organics removal, supplementing the organic reductions that occur in the lime and RO processes as needed to meet treatment standards. GAC could also be added for redundant organic removal to minimize the risk from unknown organic hazards.

Figure 3 shows process Treatment Alternatives 1 and 4. Both process trains are able to meet groundwater nondegradation standards with a partial plant flow processed through the denitrification filters and GAC process units, and are then referred to as Treatment Alternatives 1A and 4A. Table 3 indicates which processes are used in each treatment alternative and what percent flow is processed, along with the resulting product water quality. As can be seen in Table 3, Treatment Alternatives 2 and 3 are similar to Treatment Alternative 1, but with reduced denitrification, RO, and GAC flows. Similarly, Treatment Alternative 5 is similar to Treatment Alternative 4, but with reduced denitrification and GAC flows. The Treatment Alternatives 2, 3 and 5 are only able to meet the composite water quality standards.

The RO process removes salts, metals, and organics, concentrating these constituents in to reject brine flow stream. The RO brine requires treatment and disposal. The RO brine treatment method affects the total groundwater recharge treatment plant's influent

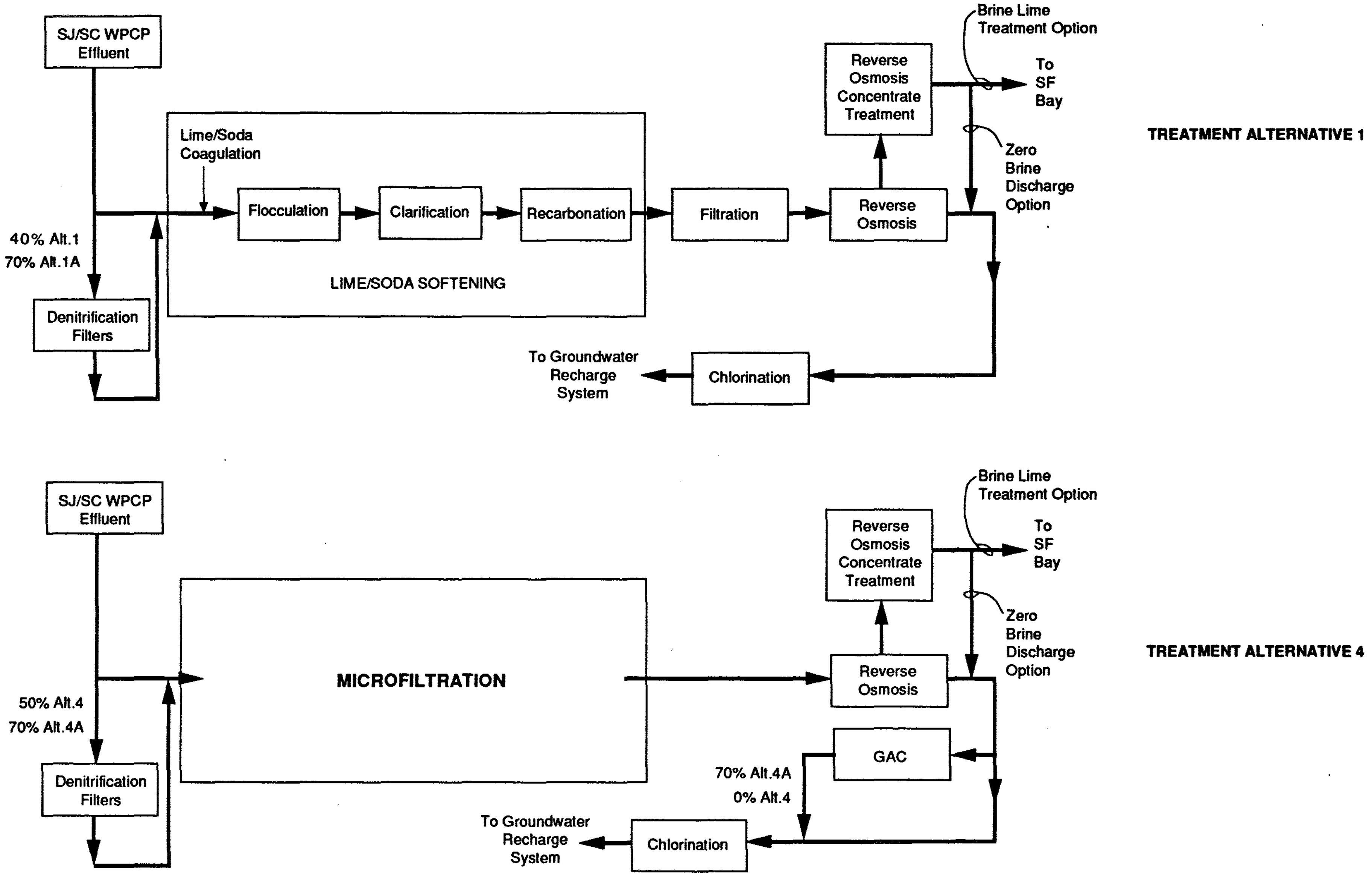

FIGURE 3
TREATMENT ALTERNATIVES

Table 3
Selected Water Quality and Process Data

Treatment Alternative	Treatment Standard	Product Water Quality			Percent Plant Flow Processed						
		TDS	NO_3 as N	TOC	Denitrification Filters	RO	GAC	Lime	Filtration	Microfiltation	Chlorination
1	Composite	61	5.7	1.0	40	Δ	0	Δ	Δ	0	Δ
2	Composite	385	5.6	2.1	70	60	40	Δ	Δ	0	Δ
3	Composite	61	9.1	1.0	0	Δ	0	Δ	Δ	0	Δ
4	Composite	61	4.9	1.6	50	Δ	0	0	0	Δ	Δ
5	Composite	61	9.1	1.6	0	Δ	0	0	0	Δ	Δ
1A	Nondegradation	61	3.2	1.0	70	Δ	0	Δ	Δ	0	Δ
4A	Nondegradation	61	3.2	1.0	70	Δ	70	0	0	Δ	Δ
Groundwater Nondegradation Standard		350	3.2	1.0							
Composite Standard											
20% Dilution		350	10	4							
50% Dilution		350	5.8	4							

Notes:
RO brine treatment method does not affect treatment plant product water quality.

- 0 Percent plant flow processed
Δ 100 Percent plant flow processed

quantity. With the lime brine treatment option, 25 mgd must be processed through the upstream processes to obtain 20 mgd of reclaimed water effluent. With the zero discharge brine treatment option, only 20 mgd of influent is necessary to produce the 20 mgd of reclaimed water effluent.

Dilution water used for direct injection well recharge requires coagulation, filtration, and chlorination to remove suspended solids. This treatment will also prevent biomass growths. This treatment is necessary because suspended solids and biomass growths would clog the injection wells.

Treatment Residuals

The groundwater recharge treatment plant would produce several waste residuals that would include, depending on the selected processes, RO brine, lime sludge, spent GAC, and filter and carbon absorber backwash water. All of these residuals concentrate the metals from the waste stream. Brine disposal to the South Bay without an outfall would probably not be allowed because of regulatory constraints.

The RO brine residual presents the most difficult disposal challenges. The lime sludge would be dewatered to 50 percent solids and hauled to a landfill. Preliminary inquiries with regulators suggest that a permit for a spent GAC regeneration facility might technically be possible. However, cost estimates are based on offsite, out-of-state carbon regeneration because of the difficulties of obtaining an air quality permit. Recycle streams would be pumped back to the lime or microfiltration units.

Two RO brine treatment options were evaluated–lime brine and zero discharge.

- **Lime Brine.** Lime brine treatment uses high-pH lime flocculation and clarification to reduce metals in the lime effluent. The lime sludge would be dewatered and hauled to landfill. The lime brine effluent would be discharged to San Francisco Bay using a new long outfall. Preliminary estimates suggest that the lime brine discharge would meet all metal concentration limits, with the possible exception of mercury. Pilot testing and future SWRCB actions on site-specific limits will clarify the mercury limitation.

- **Zero Discharge.** Zero brine discharge treatment would use lime treatment, filtration, and additional RO processing, producing an effluent water quality that would match the main groundwater recharge treatment plant's RO effluent quality. Reject brine from the additional RO process would be further concentrated through vapor compression evaporation and forced circulation crystallization, producing a crystalline solid for encapsulation and land disposal. The additional RO and evaporation effluents would be blended with the groundwater recharge treatment plant's RO effluent to be further processed and then used for groundwater recharge.

Conveyance

Four combined treatment and conveyance/location alternatives have been identified for detailed evaluation. These alternatives are shown on Figure 3 and are summarized as follows:

- Alternative 1 provides piping from the groundwater recharge treatment plant near SJ/SC WPCP to the three SCVWD surface recharge facilities (Coyote, Los Gatos, and Guadalupe), sized for 20 mgd of reclaimed water.

- Alternative 2 provides combined groundwater recharge/nonpotable piping from the Zanker Road nonpotable treatment site to the Golden Triangle area, the approximate limit of the current nonpotable reuse project, with piping sized for the nonpotable flow plus the treatment plant influent, either 20 or 25 mgd depending on the brine treatment method. The remaining groundwater recharge plant influent is conveyed to the groundwater recharge treatment plant near the SCVWD surface recharge facilities, with the conveyance sized for the treatment plant influent only. The cost estimate was developed by subtracting the nonpotable only costs from the combined costs, thereby reflecting only the additional increment for the groundwater recharge conveyance.

- Alternative 3 is similar to Alternative 4. However, specific direct injection areas were not determined because of limited injection capacity.

- Alternative 4 will provide dilution water piping from the SCVWD Central Pipeline to the groundwater recharge treatment plant near SJ/SC WPCP sized for 20 mgd. Then combined recharge piping (reclaimed water plus dilution water) sized for 40 mgd is provided from the treatment plant to the direct injection recharge wells located in the groundwater aquifer forebay area. Current groundwater work has suggested the feasibility of direct injection in one 25-mgd well field. The groundwater model simulations indicate that an additional 15 mgd (25 mgd + 15 mgd = 40 mgd total recharge water) can likely be recharged into the basin. Determining approximate locations for an additional 15 mgd of direct injection capacity was not part of the scope of this study. A conceptual conveyance drawing for this alternative is shown on Figure 1. Cost estimates are based on a total of 19 direct injection wells, each assumed to be 24 inches in diameter and 500 feet deep, with 200 feet of screen.

Project Costs

Order-of-magnitude cost estimates are presented in Table 4 for three of the four combined treatment and location/conveyance alternatives; a cost estimate for Alternative 3 was not prepared because the alternative is not considered feasible. The estimates are not based on engineering drawings, but are based on published cost information and on scale-up or scale-down of costs from similar existing facilities. Annual repayment of the capital cost is based on a discount rate of 8-7/8 percent over a 20-year economic life. The estimates are intended only for preliminary planning and comparison of alternatives. The estimates are in 1993 dollars and are expected to be accurate within +50 to -35 percent. The cost estimates do not include the price of land, piles, or initial financing costs. The costs also do not include planning, Environmental Impact Reports (EIRs), demonstration plant testing, health effect studies, or public education efforts.

The average estimated project costs are summarized in Table 4, listing ranges for each treatment plant location and method of brine disposal. Project cost estimates range from approximately $1,600 per acre-foot to $2,800 per acre-foot, with the average water cost estimates ranging from $1,700 per acre-foot to $2,700 per acre-foot. For similar project alternatives, there is an average cost increase of approximately $240 per acre-foot when increasing the level of treatment from that meeting composite standards to that meeting nondegradation standards. All RO lime brine disposal alternatives include water costs of $353 per acre-foot for a new outfall. Capital cost estimates range from $124 million to $292 million, with the average capital costs ranging from $135 million to $289 million. All RO lime brine disposal alternatives include capital costs of $65 million for a new outfall. Annual operation and maintenance (O&M) costs range from $18 million to $35 million, with the average O&M costs ranging from $20 million to $33 million. The groundwater recharge project associated with these costs will develop 20 mgd or 22,000 acre-ft/yr of supply. In comparison, the City/SCVWD's mid-sized nonpotable project, A1-Golden Triangle, is estimated at a capital cost of $57 million, with a 1993 unit capital cost of $545 per acre-foot, developing 10 mgd annual average (21 ADWF) or 11,270 ac-ft/yr of water supply (Ref. 1-2).

Detailed cost breakdowns by treatment alternative as well as overall project alternative can be found in the Background Summary Report, Volume 2. For example, the

Table 4
Average Estimated Project Costs[a]

Project Alt. No.[h]	Plant Location/Brine Disposal Alternative[b]	Capital[d] ($1,000,000)			O&M Costs ($1,000,000/yr)			Annual Cost ($1,000,000) Total	Water Cost[f] ($ per acre-foot) Total
		Treatment[c]	Conveyance[g]	Total	Treatment[e]	Conveyance[g]	Total		
Composite Standards									
1	WPCP/LB	$157	$47	$204	$19	$1	$20	$43	$1,903
2	Forebay/LB	$157	$55	$212	$19	$1	$20	$43	$1,920
4	WPCP/LB	$174	$96	$271	$23	$2	$25	$55	$2,440
1	WPCP/ZD	$94	$46	$140	$24	$1	$25	$40	$1,806
2	Forebay/ZD	$94	$41	$135	$24	$1	$25	$39	$1,759
4	WPCP/ZD	$111	$87	$197	$28	$2	$30	$52	$2,302
Nondegradation Standards									
1	WPCP/LB	$176	$47	$223	$22	$1	$23	$48	$2,124
2	Forebay/LB	$176	$55	$231	$22	$1	$23	$48	$2,141
4	WPCP/LB	$193	$96	$289	$26	$2	$28	$60	$2,662
1	WPCP/ZD	$112	$46	$158	$27	$1	$29	$46	$2,044
2	Forebay/ZD	$112	$41	$153	$27	$1	$28	$45	$1,997
4	WPCP/ZD	$129	$87	$216	$31	$2	$33	$57	$2,540

[a] All estimated costs are in 1993 dollars. Water costs are the annualized sum of capital and O&M costs based on a discount rate of 8-7/8% and 20-year economic life. Average costs are presented for treatment alternatives meeting the composite standard (Treatment Alternatives 1,2,3,4,5) and for treatment alternatives meeting the nondegradation standard (Treatment Alternatives 1A, 4A).

[b] Groundwater recharge treatment plant locations: WPCP = near SJ/SC WPCP, Forebay
Brine Disposal Options: LB = lime brine treatment with outfall, ZD = zero brine discharge

[c] Treatment capital costs include outfall capital costs of $65.0 million for alternatives with the lime brine disposal option.

[d] Capital costs include a 20% allowance for engineering, legal, and administrative costs.

[e] Treatment O&M costs include outfall O&M costs of $860,000 for alternatives with the lime brine disposal option.

[f] Water costs are based on production of 20 mgd (22,400 ac-ft/yr) and include outfall costs of $353/AF for alternatives with the lime brine disposal option.

[g] Conveyance costs identical for all alternatives using lime brine treatment and outfall disposal.

[h] Alternative numbers correspond to those shown in Figure 3.

Table Updated February 1993

following presents a more detailed breakdown for Treatment Alternative 1A as it is combined with the three overall project alternatives:

- Treatment Alternative 1A (groundwater nondegradation standards) combined with Project Alternative 1 has a $2,055 per acre-foot water cost estimate with the lime brine disposal option, and a $1,964 water cost estimate with the zero brine discharge disposal option. The groundwater treatment plant would be located near SJ/SC WPCP, and the groundwater recharge would use the existing SCVWD surface recharge facilities.

- Treatment Alternative 1A (groundwater nondegradation standards) combined with Project Alternative 2 has a $2,073 per acre-foot water cost estimate with the lime brine disposal option, and a $1,916 water cost estimate with the zero brine discharge disposal option. The groundwater treatment plant would be located near SCVWD headquarters, and the groundwater recharge would use the existing SCVWD surface recharge facilities.

- Treatment Alternative 1A (groundwater nondegradation standards) combined with Project Alternative 4 has a $2,593 per acre-foot water cost estimate with the lime brine disposal option, and a $2,459 per acre-foot water cost estimate with the zero brine discharge disposal option. The groundwater treatment plant would be located near SJ/SC WPCP, and the groundwater recharge would use new direct injection facilities.

  The approximate $500 per acre-foot difference between Project Alternatives 1 and 4 is the increased dilution water treatment costs and increased conveyance costs. They are approximately equal parts of the total difference. The $250 per acre-foot increased conveyance costs can be further itemized as approximately $50 per acre-foot for a new dilution water supply pipeline, $40 per acre-foot for 19 injection wells, and $160 per acre-foot for increased pumping and piping costs.

Program Uncertainties

Several program uncertainties exist for the groundwater recharge project. Among the uncertainties are public acceptance, risk to groundwater, regulatory unknowns, health effects unknowns, quantity of water that can be recharged, and treated reclaimed water quality.

Public Acceptance

Public acceptance of groundwater recharge using reclaimed water is the first program uncertainty. Public acceptance can be improved by a public education program and by access to a pilot testing program. However, it is difficult to predict the degree of obtainable public acceptance. Drinking water quality is a highly volatile and sensitive subject in the San Jose area. The recent case of stream recharge by using treated groundwater contaminated by IBM met with great public resistance.

Risk to Groundwater—TOC

Risk to the groundwater from unknown or hazardous TOC contamination is a concern that must be addressed because the groundwater basin is a water supply storage and conveyance system. TOC quantity alone is not the issue; the quantities and health effects of specific organic compounds are also of concern. In considering standards for groundwater recharge, it has been suggested that the composition of TOC in imported or surface water might reflect a more natural organic content, while TOC in SJ/SC WPCP effluent might reflect a more manmade, industrial content, posing a greater risk to public health when injected into the groundwater. The risk to the groundwater basin comes from known chemicals and also from unknown chemicals where maximum contaminant levels may be imposed or allowable concentration limits reduced at some future time.

It is usually difficult to identify a significant percentage (typically no more than 5 percent) of TOC constituents in domestic waters and wastewaters. This point is substantiated by the SJ/SC WPCP 1991 effluent data where less than one percent of specific organic constituents were identified.

Reducing overall TOC quantities may reduce the quantities of compounds of concern and thus the associated risk. The DOHS draft groundwater recharge regulations approach the issue of organic compound risk by reducing the maximum allowable TOC as the percentage of reclaimed water increases and as the recharge method becomes more direct (see Table 1). Separate processes for removing organics will act as multiple barriers to decrease the risk of process breakdowns and increase reliability. Processes that remove organics include high pH lime, RO, and GAC. Risk from unknown chemicals may also be reduced by increasing process redundancies. Increasing the percent of the treatment plant flow that passes through GAC may be desirable to decrease the risk from organic chemicals.

The recommended approach for resolving the TOC content issue is a limited pretreatment program inventory of chemicals being used in the community, chemical analysis of the groundwater recharge treatment plant, and "challenge" testing. "Challenge" testing is defined as adding organic compounds to the plant influent to determine the capabilities of the plant to remove various organics. To conduct challenge testing, various samples, listed as follows, will be analyzed for organics using a gas chromatograph mass spectrometer (GC/MS), and results will be compared during pilot testing:

- Groundwater (both chlorinated and unchlorinated)
- Imported water
- Reclaimed water
- SJ/SC WPCP effluent/demonstration plant influent
- Treated water from SCVWD water treatment plants (WTPs)

Challenge testing is a key element in resolving TOC content. During pilot studies, the demonstration plant influent will be spiked with high concentrations of various manmade organic chemicals, and then the reclaimed water effluent will be tested for removal efficiencies. The demonstration plant influent and effluent GC/MS graphs will be compared to determine whether similar spikes exist, indicating spiked chemical breakthrough. The Denver Direct Potable Reuse Demonstration Plant demonstrated highly reliable removal efficiencies, which led to an increased confidence in the reclaimed water processes.

Regulatory Uncertainty

In today's regulatory environment, drinking water standards are being set with lower limits. The EPA is forced by law to regulate additional drinking water constituents annually; in recent years, most newly set maximum contaminant levels (MCLs) have been for organic compounds that are suspected of causing cancer or reproductive defects. It is probable that future regulations will either regulate new trace organics or lower the acceptable concentrations. Acceptable brine disposal methods will also have to be explored with the appropriate regulatory agencies so that the aquatic life in the Bay is not harmed.

Health Effects Uncertainty

The regulations for drinking water now govern carcinogenic, mutagenic, and teratogenic (cancer-causing and reproductive defect-causing chemicals) organic chemicals at concentrations of parts per billion (ppb). The health effects of specific organic compounds may be resolved by long-term health effect studies being completed in Denver, San Diego, and Tampa.

Water characterization and challenge testing during pilot testing may identify specific organic chemicals that have poorly defined health effects. In this event, additional short- or long-term health effect studies may be required.

New standards or methods of health effects testing could be developed in the future that might change the approach to groundwater recharge projects.

Acceptable Water Quality Standards

Two water quality standards have been discussed–the groundwater nondegradation standards and the composite standards. The water quality standard acceptable to the City and to the SCVWD has yet to be determined, especially considering that the SCVWD has chosen in the past to provide higher-quality water than the mandatory drinking water standards.

Although estimates have been made for the treated reclaimed water quality, pilot testing is required to determine the actual achievable water quality.

Aquifer Recharge Capability

Ability to recharge 20 mgd continuously is constrained by:

- Aquifer capacity. Additional groundwater modeling simulations may reduce some aquifer capacity uncertainty. The most significant uncertainty in aquifer capacity lies in assumed aquifer properties. Assumed aquifer properties may vary from location to location and may result in aquifer capacity estimates which vary by as much as plus or minus 50 percent.
- Amount of local and imported water recharged.
- Amount of groundwater pumped by water purveyors.
- In dry years recharge may be limited by lack of dilution water, and in wet years reclaimed water would compete with local water supplies for recharge capacity in existing recharge ponds.

Process Reliability

Treated reclaimed water must meet health and safety requirements. Process reliability is a concern that must be addressed. Upsets in plant operations could result in a lower-quality product water. This uncertainty is reduced by redundant process units that lower the likelihood of significant process breakdowns. In addition, product water quality would be monitored and not conveyed to reuse if effluent water quality standards were not met.

Conclusions

The significant conclusions of this Background Summary Report are:

- Health effects studies and animal testing done for other reuse projects can probably be applied to the SJ/SCVWD project, pending water characterization studies.

- Groundwater modeling results and limitations are presented as follows, indicating that 20 mgd of reclaimed water can be recharged into the Santa Clara Valley subbasin using direct injection or possibly surface recharge methods while meeting the DOHS regulatory requirements:

    - Dilution and reclaimed water are blended to a 50/50 mixture before recharge, and the minimum residence times are 150 percent of the DOHS standard.

    - With both surface and direct injection recharge, some wells need to be abandoned to meet DOHS criteria, either minimum horizontal separation or minimum residence time. The depth to groundwater criterion is not met for surface recharge. The DOHS and RWQCB might be persuaded to disregard this requirement because the reclaimed water meets direct injection water quality standards, but additional water supply wells might need to be abandoned.

    - Results from the two simulations indicate that it is feasible to recharge 20 mgd reclaimed water, based only on the simulation input conditions, with properly placed direct injection wells. This result is based on the condition that some water supply pumping wells are redistributed to the forebay area near the direct injection wells, reducing the localized high groundwater conditions caused by the direct injection. Additional unknowns not accounted for in this model, such as actual soil conditions or water chemistry, may alter these results. Other results include the following:

      The areas between Los Gatos Creek and Guadalupe River and north and west of Los Gatos Creek, appear to be more promising for direct injection of large quantities of water than the Santa Teresa Basin (the area near the Coyote recharge ponds).

      Results suggest that groundwater levels in some areas of the basin may approach steady state conditions, balancing recharge flows into and water supply flows pumped out of the basin, before reaching the maximum acceptable aquifer level.

Hydrographs suggest that the Santa Teresa Basin (the area near the Coyote recharge ponds) is not directly influenced by the injection wells in the other basins, and that groundwater levels exceeding the maximum acceptable level result only from high natural recharge in wet years.

Water levels in many parts of the basin rise under average conditions, but did not reach the maximum acceptable level during the simulation period.

  - Direct injection of 20 mgd of reclaimed water (40 mgd of recharged water) in the forebay area appears feasible, subject to more site-specific analysis. One well field of between 12 and 16 injection wells could inject between 25 and 30 mgd. This well field would require that between 1 and 17 production water wells be abandoned, with an approximate total pumping capacity of between 1 and 1,200 ac-ft/yr.
  - Direct injection of significant quantities of reclaimed water near San Francisco Bay and SJ/SC WPCP is not practical due to very limited injection well capacity in this area.
  - Dilution water used for direct injection will require treatment to prevent clogging of the injection well and surrounding aquifer. The treatment will consist of coagulation and direct filtration to reduce the total suspended solids (TSS) to approximately 1 milligram per liter (mg/l). A chlorine residual of approximately 1 mg/l will be provided to prevent well fouling from biological growth.
  - In extremely dry years, lack of available dilution water may limit the ability to recharge reclaimed water by either surface spreading or injection wells.
  - In extremely wet years, lack of recharge capacity may limit the ability to recharge reclaimed water by surface spreading.

- Treatment processes to meet groundwater nondegradation standards would include denitrification, high pH lime, filtration, RO, and disinfection, and, possibly, GAC and microfiltration.

- High-quality reclaimed effluent can be produced, meeting the groundwater nondegradation requirements of less than 3 mg/l nitrogen (N), 1 mg/l TOC, and 350 mg/l TDS.

- Two RO brine treatment residual disposal methods have been identified: lime treatment and disposal using a new outfall; and zero discharge brine treatment using additional RO, evaporation, and crystallization of solids with landfill disposal.

- Several viable conveyance alternatives have been determined, including both separate and combined nonpotable and groundwater recharge conveyance piping, to connect the source of reclaimed water (SJ/SC WPCP) with the groundwater recharge treatment plant. The new treatment plant may be located near SJ/SC WPCP or in the forebay. Conveyance piping is also required to convey lime brine effluent to the San Francisco Bay outfall if lime brine treatment is used, and dilution water to the injection well site if direct injection recharge is used.

- Project cost estimates range from approximately $1,600 per acre-foot to $2,800 per acre-foot, with the average water costs ranging from $1,700 per acre-foot to $2,700 per acre-foot. All RO lime brine disposal alternatives include water costs of $353 per acre-foot for a new outfall with all lime brine options. Capital cost estimates range from $124 million to $292 million, with the average capital costs ranging from $135 million to $289 million. All RO lime brine disposal alternatives include capital costs of $65 million for a new outfall with all lime brine options. Annual O&M costs range from $18 million to $35 million, with the average O&M costs ranging from $20 million to $33 million.

  All costs are order-of-magnitude accuracy, expressed in 1993 dollars, and include only the full-scale project costs, including an allowance for engineering, legal, and administrative costs. Annual capital cost repayments are based on a discount rate of 8-7/8 percent over a 20-year economic life. Estimates do not include costs for land, piles, financing/ loan origination, planning, public education program, pilot testing, EIRs or health effect studies.

Recommendations

Should the groundwater recharge project proceed, the next steps to resolve project uncertainties would be as follows:

- Pilot testing to determine actual achievable product water and residual qualities.

- Implement pilot testing by:

    - Completing the Demonstration Plant process selection and Plan of Study report–Tasks 3 and 4 of the current contracted work

    - Demonstration Plant predesign

    - Demonstration Plant design

- Operate Demonstration Plant

    - Conduct challenge testing and water characterization on Demonstration Plant effluent, including organic chemical testing and identification.

    - Design and proceed with additional specific toxicological or other health effects studies as needed to respond to challenge testing and water characterization results.

- Review the need for additional health effect studies once results from other projects are finalized.

- A limited number of additional water quality tests is recommended before proceeding with the pilot facility predesign; the remainder are tests that would be conducted during the pilot testing.

- Perform numerous groundwater model simulations holding most inputs constant while varying only one or two factors. (Rather than running only two simulations while varying numerous inputs, as completed in Simulations No. 1 and No. 2.) Perform additional simulations to:

    - Estimate the number of consecutive average years before the basin reaches the maximum acceptable level, given different input conditions.

    - Evaluate locating new water supply wells in the forebay near localized high groundwater levels to prevent the groundwater from exceeding the maximum acceptable level, while also meeting the DOHS criterion requiring a minimum of 2,000 feet of horizontal separation.

  - Optimize basin pumping and recharge to reduce local areas of high groundwater levels. One or all of the following could be varied: change the location and quantity of direct injection wells; redistribute pumping patterns using existing water supply wells; install new water supply wells in the forebay. The City and the SCVWD do not have the authority to direct water purveyor changes.

  - Improve accuracy of simulation baseline by introducing a statistically likely climatological regime to reproduce the natural fluctuations of atmospheric conditions and corresponding pumping rates, creating a more accurate representation of wet/average/drought periods.

  - Refine the definition of the maximum acceptable groundwater level and clarify the impact of exceeding this level: allow the definition of maximum acceptable level to vary at different locations in the basin; determine what problems arise when the groundwater level exceeds the maximum acceptable level, and identify how high groundwater levels could trigger these problems.

- Conduct the following additional groundwater work to improve the accuracy of the very preliminary groundwater modeling results and DOHS criteria predictions:

  - Collect site-specific data, including depth to groundwater, hydraulic parameters (transmissivity, storativity, and porosity), and groundwater quality. This is particularly needed in the direct injection well field area if the project proceeds based on direct injection recharge.

  - Do additional local model studies on the Los Gatos Creek and Guadalupe River surface recharge facilities if the project proceeds based on surface recharge.

  - Field check nearby well locations, well status, well construction, and well use.

  - Conduct specific transient groundwater flow calculations using an enlarged version of the basinwide model with an attached particle-tracker.

  - Pilot test injection well.

References

1-1 CH2M HILL. Reconnaissance Investigation of Reclamation Opportunities in Northern Santa Clara County. Prepared for the City of San Jose by CH2M HILL. March 1990.

1-2 CH2M HILL. Final Golden Triangle Nonpotable Reclamation Project Facility Plan. Prepared for the City of San Jose and the Santa Clara Valley Water District. January 20, 1992.